2009-2010 Validation Scenario

And

1900 Validation Scenario Report

Idaho Department of Water Resources

Allan Wylie

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DRAFT

Contents

Abstract

The Idaho Department of Water Resources (IDWR) recently developed a new version of the Eastern Snake Plain Aquifer Model under guidance of the Eastern Snake Hydrologic Modeling Committee. Version 2.0 of the model was calibrated by comparing model output with aquifer water levels, river gains, spring discharges, and spring reach gains from between May 1985 through October 2008. After calibration, the IDWR chose to validate ESPAM2.0 with two scenarios, a 2009-2010 Validation Scenario and a 1900 Validation Scenario. The 2009-2010 scenario took advantage of data that became available during calibration, and the 1900 scenario used data from reports published by the State Engineer and historical USGS documents.

To evaluate the 2009-2010 Validation Scenario, the 1985-2008 calibration period and the 2009-2010 validation period were divided into 12 roughly two-year periods. The Root Mean Squared Error (RMSE) and the Median Absolute Deviation (MAD) were computed for each of the 12 periods for four model output categories (i.e. aquifer water levels, river gains, spring reach gains, and spring discharges). The unweighted RMSE and MAD for the 2009-2010 validation period fell within the bounds generated from the calibration period, the weighted RMSE and MAD also fell within the bounds for generated from the calibration period for every category except for spring discharges. Suggesting that the model may tend to over predict future spring discharges.

The 1900 scenario took advantage of data located in Biennial Reports of the State Engineer (Mills, 1896: Ross, 1900; Ross 1902), Russell (1902), Nace (1958), and the Parameter-elevation Regression on Independent Slopes Model (PRISM) data sets. These sources provided crop mix, crop yield, acres irrigated, a few water level observations collected in wells, spring discharge measurements and estimates, and precipitation data from around 1900. This allowed creation of model input data sets to simulate aquifer water levels and spring discharge from around 1900. Model output for the 1900 Validation Scenario tends to provide an acceptable fit between model output and the field observations.

Introduction

The Eastern Snake Plain extends from Ashton, Idaho in the northeast to King Hill, Idaho in the southwest (Figure 1). The population is generally sparse, with most people residing near the Snake River. Much of the land is federal, managed by the U.S. Bureau of Land Management. Extensive portions of the federal land are covered by rugged basalt outcrops.

The climate is arid to semi-arid with precipitation ranging from 8 to 14 inches per year, and irrigation is required to grow most agricultural crops. Irrigation began in the late 1800s using water from the Snake River and its tributaries (Garabedian, 1992). The number of acres irrigated with surface water increased until about the mid-1940s, and has since been declining as the number of ground water irrigated acres increased beginning in the 1950s. Irrigation practices continue to change in response to technology and economic factors (Cosgrove and others, 2006).

Water use on the Eastern Snake Plain has been affected by legal developments, including adjudication, a moratorium on expansion of irrigated acreage, and the adoption of conjunctive management rules linking administration of ground and surface water rights.

Ground water and surface water are interconnected in the Easter Snake Plain Aquifer. This interconnection prompted the Idaho Department of Water Resources (IDWR) to develop an aquifer model under the supervision of the Eastern Snake Hydrologic Committee (ESHMC) to help administer surface water and ground water conjunctively. IDWR updated their Eastern Snake Plain Aquifer Model (ESPAM) to ESPAM2.0 in August 2012. This report documents two scenarios developed to test the veracity of ESPAM2.0.

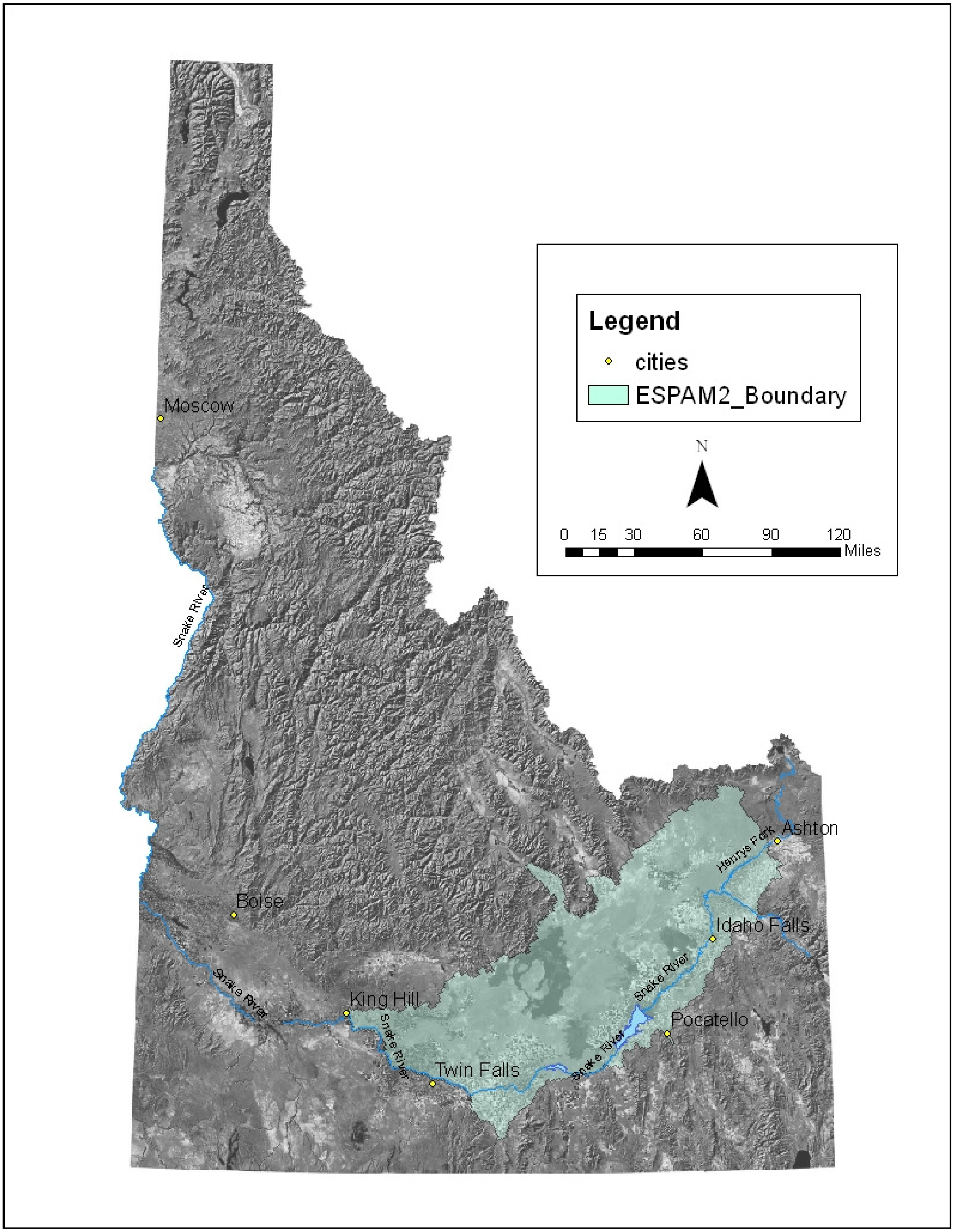


Figure 1. Location of Eastern Snake Plain Aquifer Model version 2.0.

Hydrogeologic Setting

The surface of the Eastern Snake Plain consists primarily of basalt, commonly with a thin covering of sediments. The subsurface consists of a series of thin basalt flows with occasional intercalated sediments. Flows range in thickness from a few feet to tens of feet (Welhan and Funderberg, 1997), with the collective thickness of basalt flows exceeding several thousand feet in places (Whitehead, 1986).

The Snake River flows along the southern margin of the Eastern Snake Plain and is the exclusive surface water discharge for the Eastern Snake Plain. Ground water outflow from the Eastern Snake Plain is assumed to be minimal due to the low hydraulic conductivity deposits of the Glens Ferry Formation at the interface between the Eastern and Western Snake Plain aquifers. The discharge of the ESPA occurs primarily as Snake River gains and spring discharge; therefore, the flow of the Snake River at King Hill is considered to be the basin discharge, excluding evaporation (Garabedian, 1992).

Flow Model

ESPAM2.0 is an upgrade of ESPAM1.1 (Cosgrove and others, 2006). ESPAM2.0 was developed by the Idaho Department of Water Resources and reviewed by the Eastern Snake Hydrologic Modeling Committee (ESHMC). The ESHMC is composed of hydrologists and modelers from state and federal agencies, representative of private industry and their consultants, and the University of Idaho. The ESPAM2.0 was created using MODLFOW2000, a finite-difference ground water modeling program, by Harbaugh and others (2000), and calibrated using PEST version 12.0 (Doherty, 2004). In MODFLOW, time is broken into small segments called stress periods, and the model domain is broken into grid cells. ESPAM2.0 has a uniform 1mi x 1mi grid. The 23.5-year calibration period is broken into 282 one-month stress periods preceded by a five-year warm up period consisting of 60 one-month stress periods for a total of 342 stress periods.

During calibration, model parameters such as transmissivity, aquifer storage, riverbed conductance, drain conductance, general head boundary conductance and, in this instance, certain components of the water budget, are adjusted until model generated aquifer water levels and discharges match observed values. PEST was only allowed to adjust the components of the water budget between assumed uncertainty bounds. For example, PEST could only adjust evapotranspiration (ET) ± 5 % because the ESHMC felt that ET was well known.

Model calibration targets include 43,165 aquifer water levels collected in 1,121 different wells, 1,405 river gain/loss observations, 2,485 spring discharge observations, and 1,124 spring reach targets.

2009-2010 Model validation

After model calibration, additional agricultural diversions, Snake River gain and loss data, aquifer water levels, spring discharge data and other water budget data became available allowing the IDWR to use November 2008 through September 2010 as a validation period. The water budget data was compiled and formatted for use in the model and the model was run to generate model derived river gains, aquifer head, and spring discharge output. This output was compared with field observations from November 2008 through September 2010. Field observations during the validation period included 4600 aquifer water levels collected from 355 different wells, 120 river gain/loss observations, 321 spring discharge observations, and 96 spring reach observations.

The validation period is a two-year period, and the calibration period is 23.5 years, so directly comparing the calibration period with the validation period is difficult. Issues include:

1) Even if the model fit is the same during the validation period as during the calibration period, with only two points to compare, one will have better statistics than the other.
2) The statistics may vary through time.

The IDWR requested advice from Maxine Dakins, Ph.D., a University of Idaho professor, on statistical methods for evaluating model performance. Dakins (2012) suggested dividing the 23.5-year calibration period into 11 two-year and one 1.5-year period and comparing the single two-year validation period to the distribution of values from the calibration period. Dakins (2012) also suggested using RMSE and MAD as comparison metrics.

The RMSE (Hill and Tiedaman, 2007) is calculated from the Sum of the Squared Errors (SSE).

Where: $RMSE = \sqrt{\frac{SSE}{df}}$

SSE= Sum of the Squared Errors

df = n-p

n = number of values used as calibration targets

p = number of calibration parameters

Hill and Tiedaman (2007) recommend using the same weighting scheme as during calibration. This changes the units of the observations, so this report will show RMSE and MAD both weighted and unweighted. Regardless, each aquifer water level observation was weighted the same during calibration, so weighting will have no impact on the RMSE or MAD for aquifer head data. River reach gains, spring reach gains, and spring discharges had different weights during calibration to account for variation in the magnitudes of discharge and/or the number of observations available. Statistics for these groups were calculated using both weighted and unweighted values.

MAD is the median of the absolute values of the deviation from the median of the dataset.

$$MAD = median(\left|X_i - \ medianX_j\right|)$$

Where:

X_i = the ith data point in the set

medianX_j = the median of all of the data values in the set

|| = the absolute value of the deviations.

Aquifer head

A total of 43,165 water-level measurements collected in 1,121 different wells were used during model calibration. 354 of these wells were measured during the validation period. A total of 4600 aquifer water level observations were available during the validation period for comparison with model output. Figure 2 shows the location of the 1,121 wells used for calibration and the 354 wells used for both calibration and validation

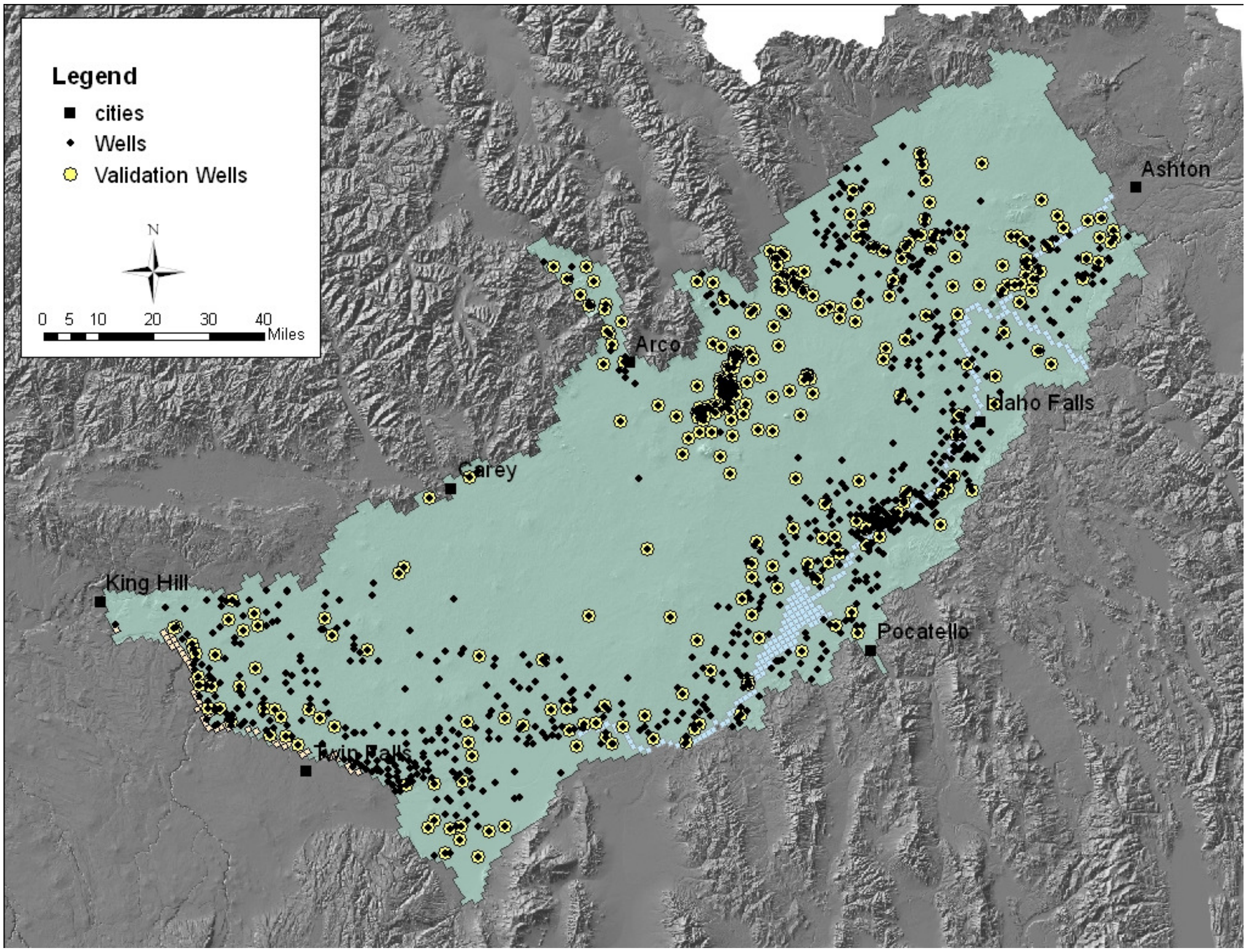


Figure 2. Location of wells used to collect aquifer head observations .

Aquifer head RMSE and MAD from the validation period were compared with the distributions of RMSE and MAD from the calibration period. During calibration, the RMSE for the 11 two-year periods and the 1.5-year period ranged from 23.6 to 31.6 ft, and the RMSE from the validation period was 24.6 ft (Figure 3). The MAD for the 11 two-year periods and the 1.5-year calibration period ranged from 12.4 to 7.3 ft, and the MAD for the validation period is 11.0 ft. Both the validation RMSE and the MAD are well within the ranges computed from the calibration data (Figure 3).

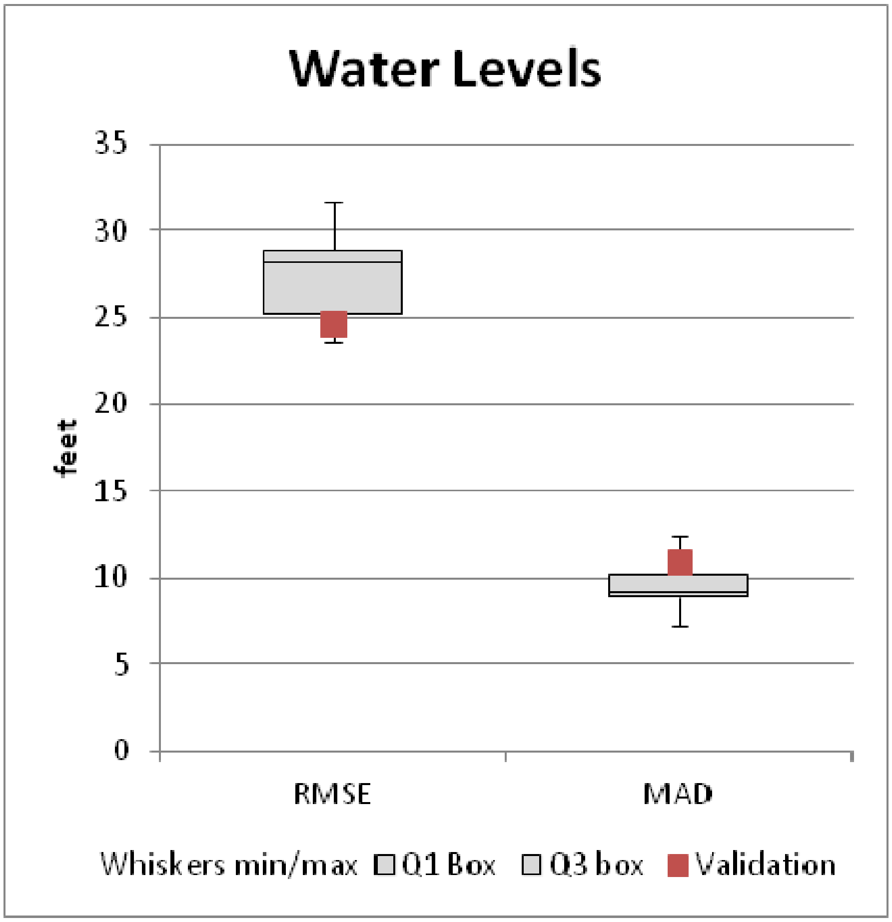


Figure 3. Comparison of RMSE and MAD for water levels.

River reach gain

The Snake River was divided into five river reaches defined by river gages operated by the United States Geological Survey (USGS). The river reach gain/loss calibration targets were computed by differencing the upstream and downstream gages while accounting for diversions, returns, tributary inflow, and changes in reservoir storage. Model calibration targets included a total of 1,405 river gain/loss observations. 120 observations were available during the validation period for comparison with model output. Figure 4 shows the locations of the five river reaches.

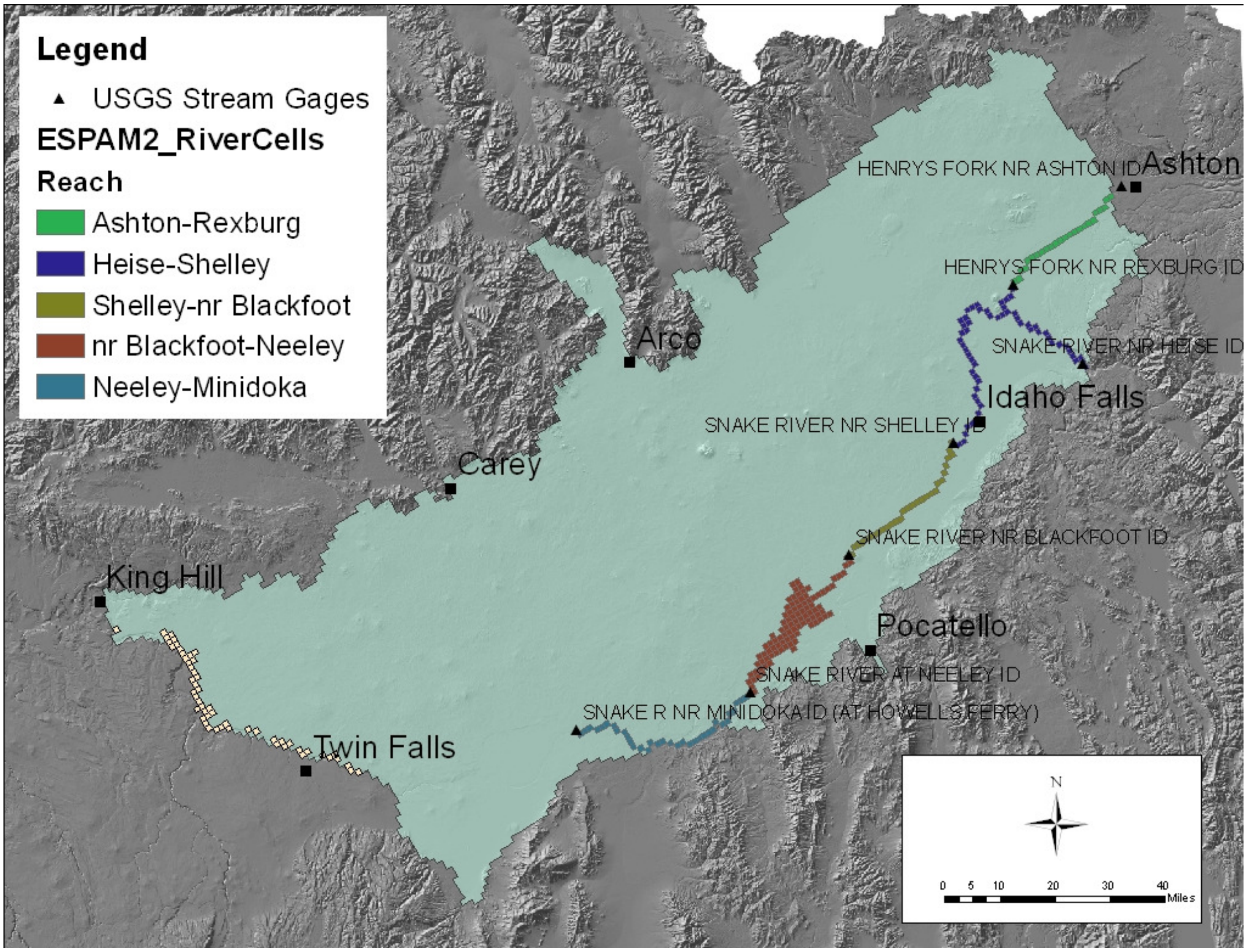


Figure 4. Location of river reaches and gages used to establish reaches.

River reach gain RMSE and MAD from the validation period were compared with the distributions of RMSE and MAD from the calibration period. These comparisons were made using both unweighted and weighted residuals. The unweighted RMSE for the 12 periods during calibration ranged from 37.9 to 80.2 cfs, and the unweighted RMSE from the validation period was 63.7 cfs. The unweighted MAD for the 12 periods during calibration ranged from 117.2 to 218.4 cfs, and the unweighted MAD for the validation period is 174.4 cfs.

The weighted RMSE for the 12 periods during calibration ranged from 3.36e-6 to 7.34e-6, and the weighted RMSE from the validation period was 5.30e-6. The weighted MAD for the 12 periods during calibration ranged from 1.07e-5 to 2.13e-5, and the weighted MAD for the validation period is 1.55e-5. Both the weighted and unweighted validation RMSE and the MAD are within the ranges computed from the calibration data (Figure 5).

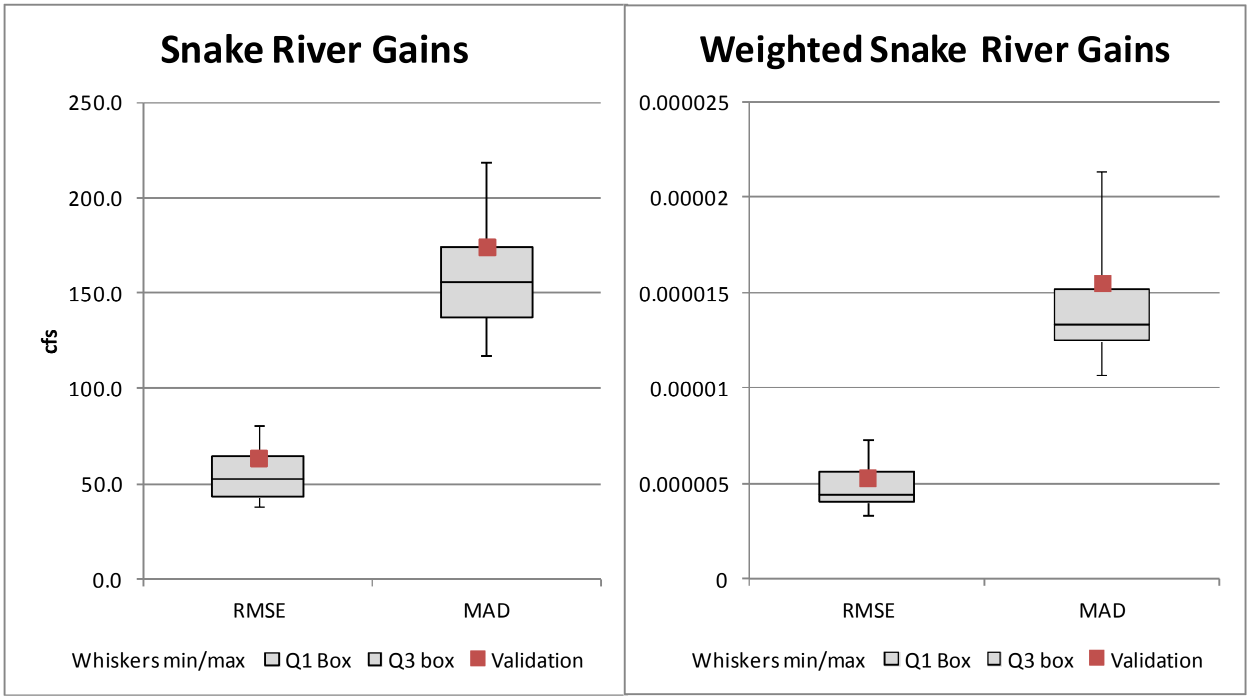


Figure 5. RMSE and MAD for Snake River gains.

Spring reach gain

The ESPA discharges from springs in the Magic Valley which extend from east of Twin Falls to King Hill. The springs are grouped into three spring reaches defined by gages on the Snake River: Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill (Figure 6). Model calibration targets included 1,124 spring reach observations. 96 observations are available during the validation period for comparison with model output.

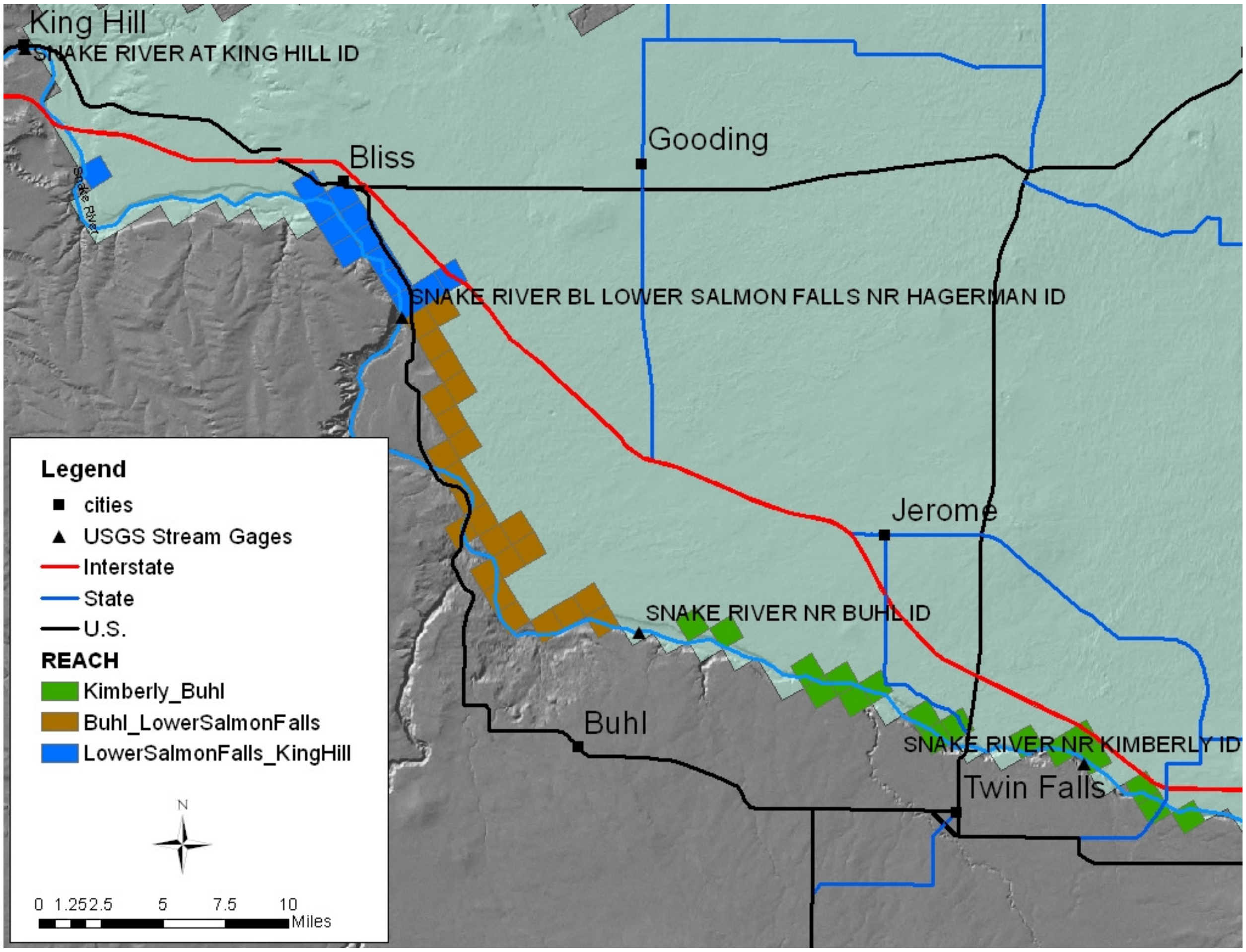
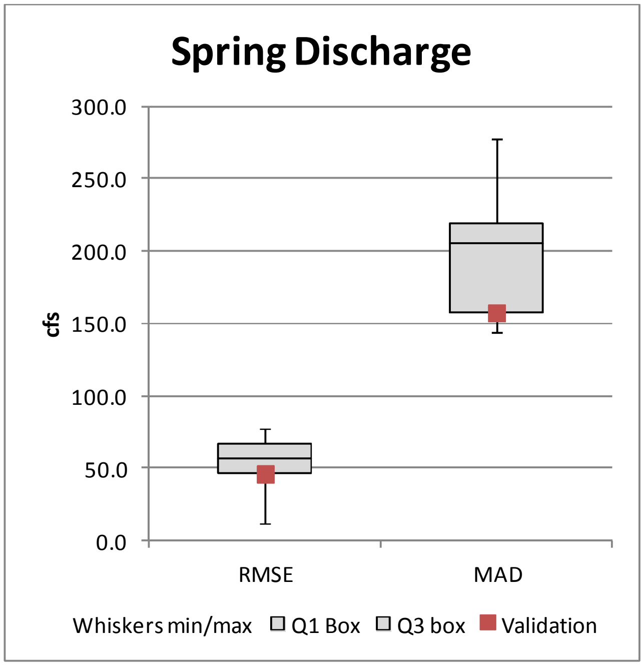


Figure 6. ESPAM2.0 spring reaches.

Spring reach gain RMSE and MAD from the validation period were compared with the distributions of RMSE and MAD from the calibration period. These comparisons were made using both unweighted and weighted residuals. The unweighted RMSE for the 12 calibration periods ranged from 12.0 to 77.6 cfs, and the unweighted RMSE from the validation period was 46.1 cfs. The unweighted MAD for the 12 calibration periods ranged from 144.2 to 277.7 cfs, and the unweighted MAD for the validation period is 157.3 cfs.

The weighted RMSE for the 12 calibration periods ranged from 3.76e-6 to 8.43e-6, and the weighted RMSE from the validation period was 4.33e-6. The weighted MAD for the 12 calibration periods ranged from 1.50e-6 to 3.15e-5, and the weighted MAD for the validation period is 1.44e-5. Both the weighted and unweighted validation RMSE and the MAD are within the ranges computed from the calibration data (Figure 7).



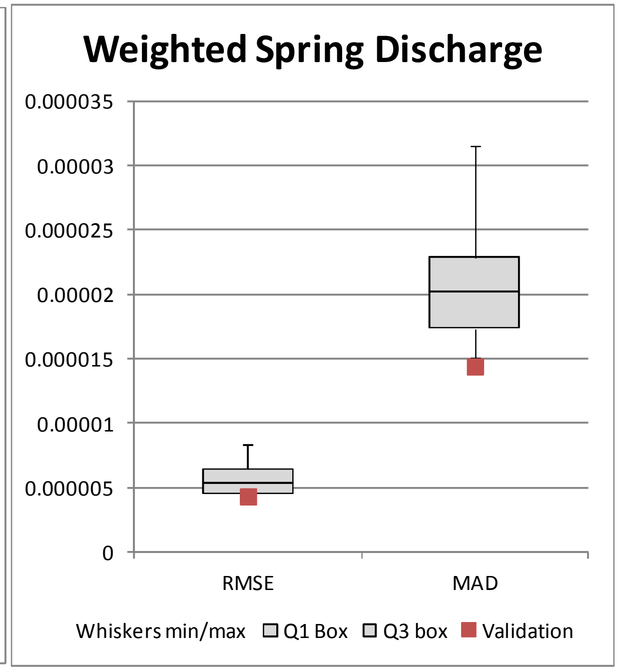


Figure 7. RMSE and MAD for Spring reaches from calibration period (box and whisker) and validation period.

Discharge for individual springs

Fourteen springs in the Magic Valley were used as transient calibration targets, these included Devils Washbowl, Devils Coral, Blue Lake, Crystal Spring, Niagara Springs, Clear Lakes, Briggs Springs, Box Canyon Springs, Sand Springs, Thousand Springs, National Fish Hatchery, Rangen Springs, Three Springs, and Malad Springs. These springs were referred to as A&B springs during model calibration. Model calibration targets included 2,485 spring discharge observations. 321 observations were available during the validation period for comparison with model output. Figure 8 shows the locations of the springs used as transient calibration targets.

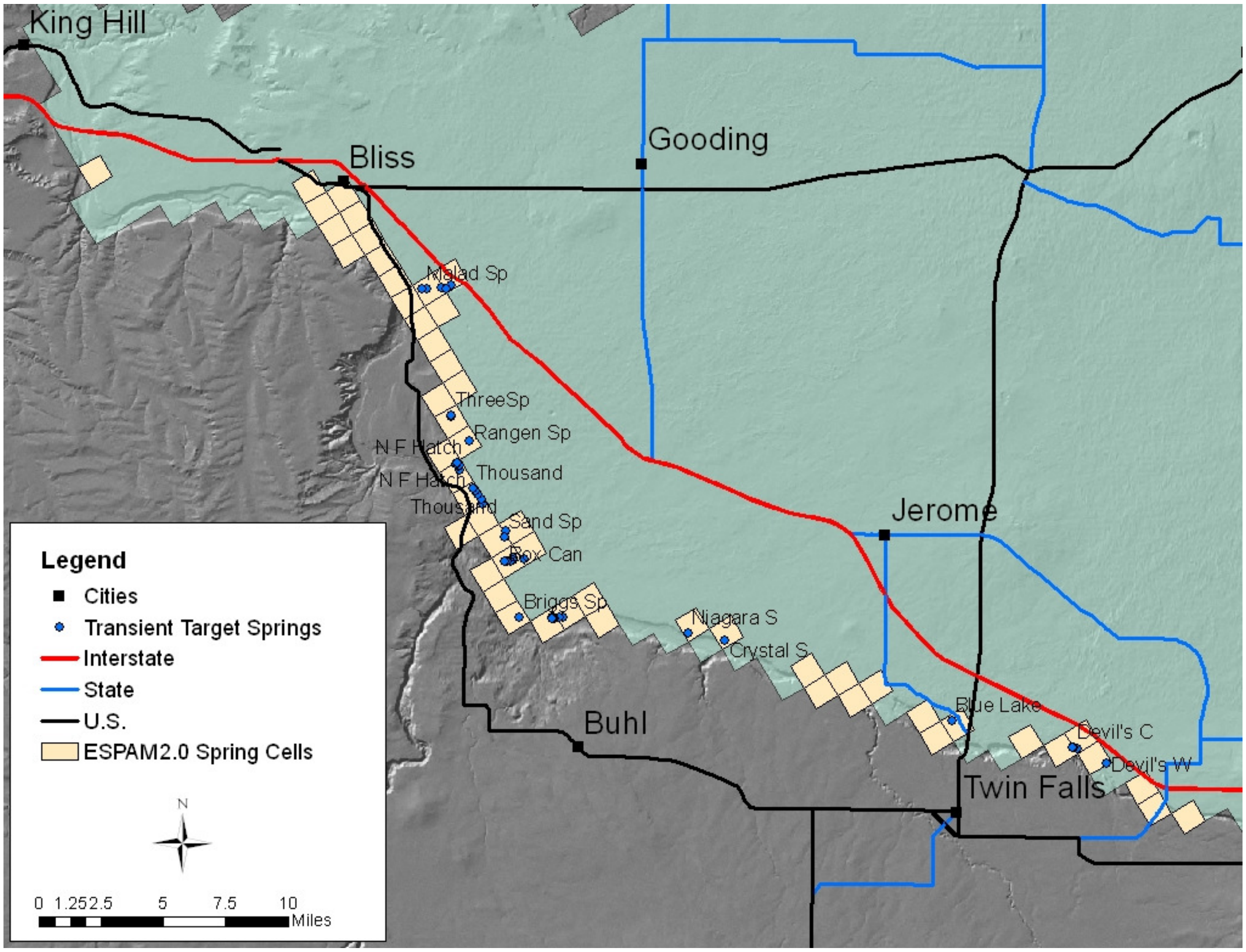


Figure 8. Location of the 14 springs used as transient calibration targets.

Spring discharge RMSE and MAD from the validation period were compared with the distributions of RMSE and MAD from the calibration period. These comparisons were made using both unweighted and weighted residuals. The unweighted RMSE for the 12 calibration periods ranged from 1.9 to 12.0 cfs, and the unweighted RMSE from the validation period was 5.2 cfs. The unweighted MAD for the 12 calibration periods ranged from 2.6 to 8.8 cfs, and the unweighted MAD for the validation period is 7.1 cfs.

The weighted RMSE for the 12 calibration periods ranged from 3.12e-6 to 6.12e-6, and the weighted RMSE from the validation period was 8.30e-6. The weighted MAD for the 12 calibration periods ranged from 6.76e-6 to 1.10e-5, and the weighted MAD for the validation period is 1.16e-5. The unweighted validation RMSE and the MAD are within the ranges computed from the calibration data, however, the weighted RMSE and MAD are higher than the ranges computed from the calibration data (Figure 9).

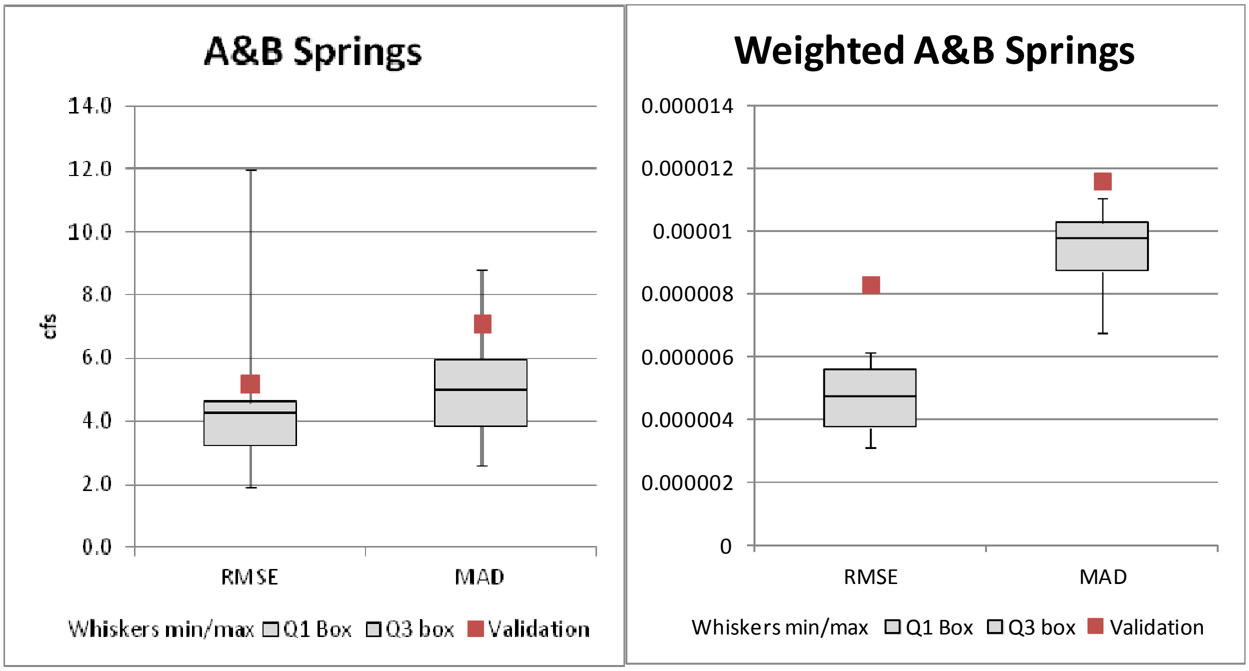


Figure 9. RMSE and MAD for discharge from A&B Springs.

1900 Model validation

The IDWR also sought to compare model output with ESPA observations collected around 1900 by the USGS (Russell, 1902) and data recorded in the 1895-1896, 1899-1900, and 1901-1902 Biennial Reports of the Idaho State Engineer (Mills, 1896; Ross, 1900; Ross, 1902). The data are not rich enough to populate a transient model, so the IDWR produced a steady state model representing 1900. This required some modifications to the original model because fewer acres were irrigated and American Falls Reservoir had not been built. Russell (1902) recorded conditions on the ESPA such as where irrigation was taking place, and noted that spring discharges did not vary seasonally. Russell (1902) also provided depth to water measurements collected in a few wells. He indicated that most of the well measurements were collected by the Oregon Short Line railroad (OSL), but he did not indicate when the measurements were collected and wells were only located by the town name.

The Biennial Reports of the State Engineer (Mills, 1896; Ross, 1900; Ross 1902) provided estimates of crop mix, crop yield, acres irrigated , and spring discharge. The spring discharges reported in Ross (1902) were measured or estimated by Jay D. Stannard between April 15 and April 28, 1902. Ross (1902) reported irrigated acres by canal along the upper Snake River. Irrigated acres in non-Snake basins overlying the ESPA were reported in Ross (1900). Irrigated acres were assigned to ESPAM2.0 irrigation entities based on these reports (Figure 10).

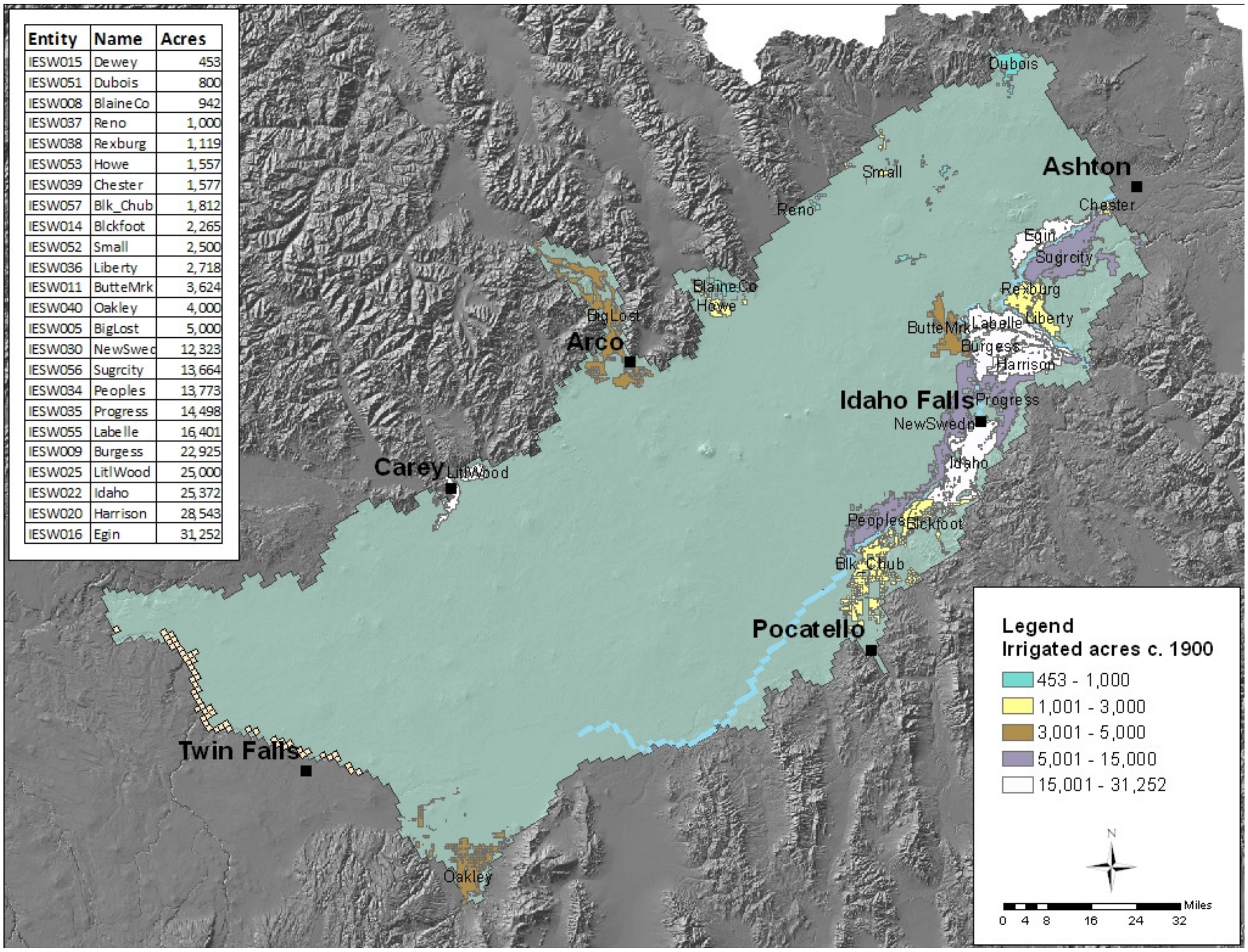


Figure 10. Irrigated acres byESPAM2 irrigation entity based on Ross (1900) and Ross (1902).

Precipitation data for 1895-1902 were obtained from the PRISM Climate Group with Oregon State University (http://prism.oregonstate.edu/). With these data, IDWR determined that the average precipitation for 1895-1902 was similar to the average for 1988-1992. IDWR then set the values for non-irrigated recharge, tributary underflow, perched river seepage, and the average annual ET to the average for 1988-1992.

Data obtained from the Biennial Reports of the State Engineers (Mill, 1896; Ross, 1900; Ross 1902) indicate that crop yields were lower in 1900. Lower crop yields may have resulted from moisture stress, lower plant density, lower ratio of harvestable material, lower resistance to disease, and other factors. ET is presumed to have been lower in 1900, but there is not sufficient information to accurately quantify the relationship between the difference in crop yields and differences in ET. For the 1900 validation, an estimated ET adjustment factor of 0.7 was applied. This factor was estimated based on crop mix and crop yields, assuming that crop yield differences resulted solely from moisture stress.

The MODLFOW river file used during calibration contains American Falls Reservoir, which was not constructed until 1927, and requires river stage as an input. While river stage was available at various gages during the calibration period, it was not available at a sufficient number of locations during the 1900 validation period. Thus, the MODFLOW Streamflow-routing (SFR) package (Prudic and others, 2004) was used for the 1900 validation simulation. American Falls Reservoir was eliminated by extending a line of SFR cells down the middle of the reservoir (Figure 11). Required input for each SFR cell includes river width, and depth but not stage. Flux at the upriver end of the river is also required. The average unregulated flow for 1988-1992 was used as an estimate for the flux into the model at the South Fork upstream from Heise and for the Henry's Fork downstream from Ashton.

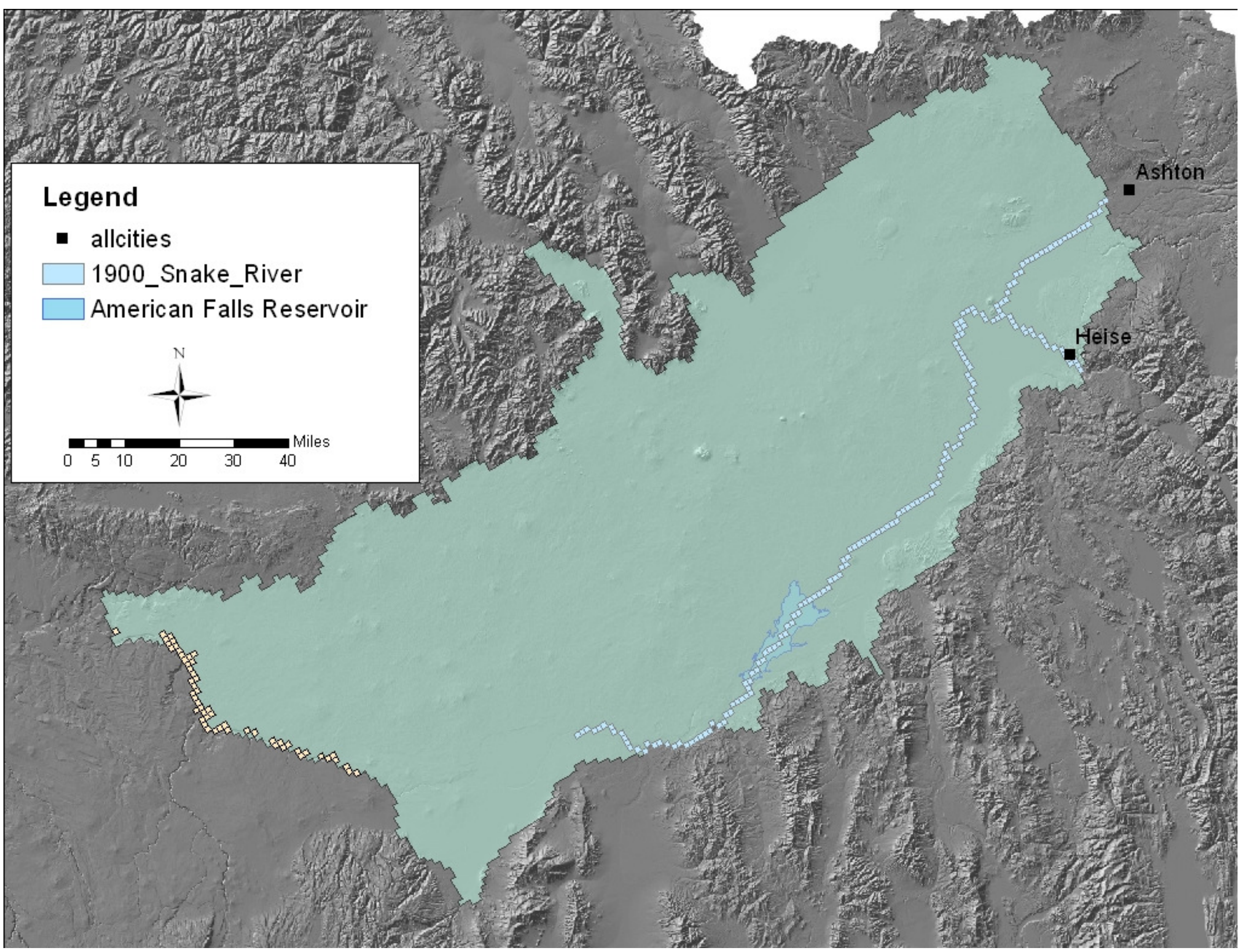


Figure 11. 1900 Snake River simulated with MODFLOW Stream Flow Routing Package (Prudic and others, 2004).

Aquifer head

All but one of the 1900 aquifer head observations reported by Russell (1902) are credited to the OSL railroad (Table 1). The data associated with the wells provided by Russell are simply town names and depth to water, no date is provided with the railroad wells to indicate when the measurement was collected. Perhaps the depth to water measurements from the OSL wells were collected by drillers when wells used to supply water to steam engines were completed. Wikipedia (http://en.wikipedia.org/wiki/Oregon_Short_Line_Railroad) indicates that the railroad line between Pocatello, Idaho and Huntington, Oregon was completed in 1884, so the wells were probably drilled and measured before 1884. Along with the railroad wells, Russell (1902) mentions a well drilled in 1890 at Gooding, Idaho in which water rose to within 110 ft of land surface. Using approximate well locations and land surface elevations, Table 1 shows the observed aquifer head prior to or at 1900, the modeled head, and the residual difference between the observed and modeled. It is interesting to note that the water elevation at Bliss is lower than most of the springs in the cell containing Bliss (Figure 12). Perhaps landslides in the Bliss area have changed the local hydrogeology. Gillerman (2001) indicates that there have been several landslides in the area, the most recent being in 1993. If landslides since 1900 have altered the local hydrogeology and the model uses modern spring elevations, the model cannot be expected to replicate the 1900 water table in the vicinity of Bliss.

Table 1. Head observations from Russell (1902).

Well	Source	Measured (ftamsl)	Modeled (ftamsl)	Residual (ft)
GOODING	Russell	3463	3329	134
OWINZA	OSL	3865	3919	-54
KIMAMA	OSL	4007	4004	3
MINIDOKA	OSL	3906	4008	-102
BLISS	OSL	2841	3067	-226

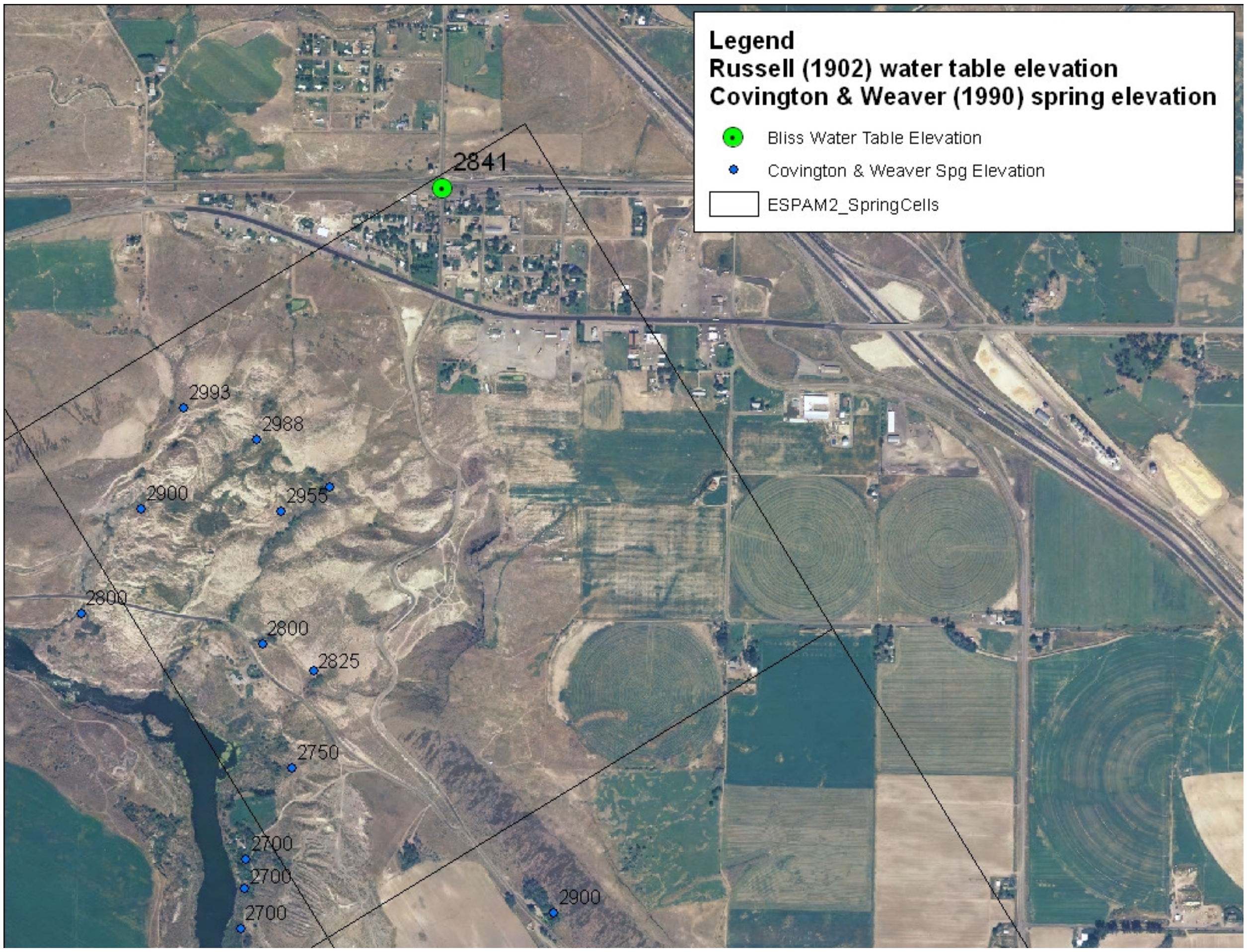


Figure 12. Water table elevation at Bliss (Russell, 1902) and spring elevations (Covington & Weaver, 1990).

Another check on the 1900 water table elevation is to compare the modeled water table with land surface elevation. Where 1900 wetlands existed, the water table should be near or above land surface; where sagebrush steppe existed, the water table should be below land surface. Wetlands existed at Market Lake near the confluence of the Henrys Fork and South Fork, at Mud Lake, Carey Lake, in the Fort Hall Bottoms north of Pocatello, and at the springs along the Snake River Canyon between King Hill, and east of Twin Falls. Figure 13 shows the location of the modeled wetlands and observed wetlands. Although there are springs emerging west of Ashton, the modeled head in this area appears excessive. The area east of King Hill appears to have a higher water table elevation than expected also. Modeled wetlands generally correspond with the location of historic wetlands.

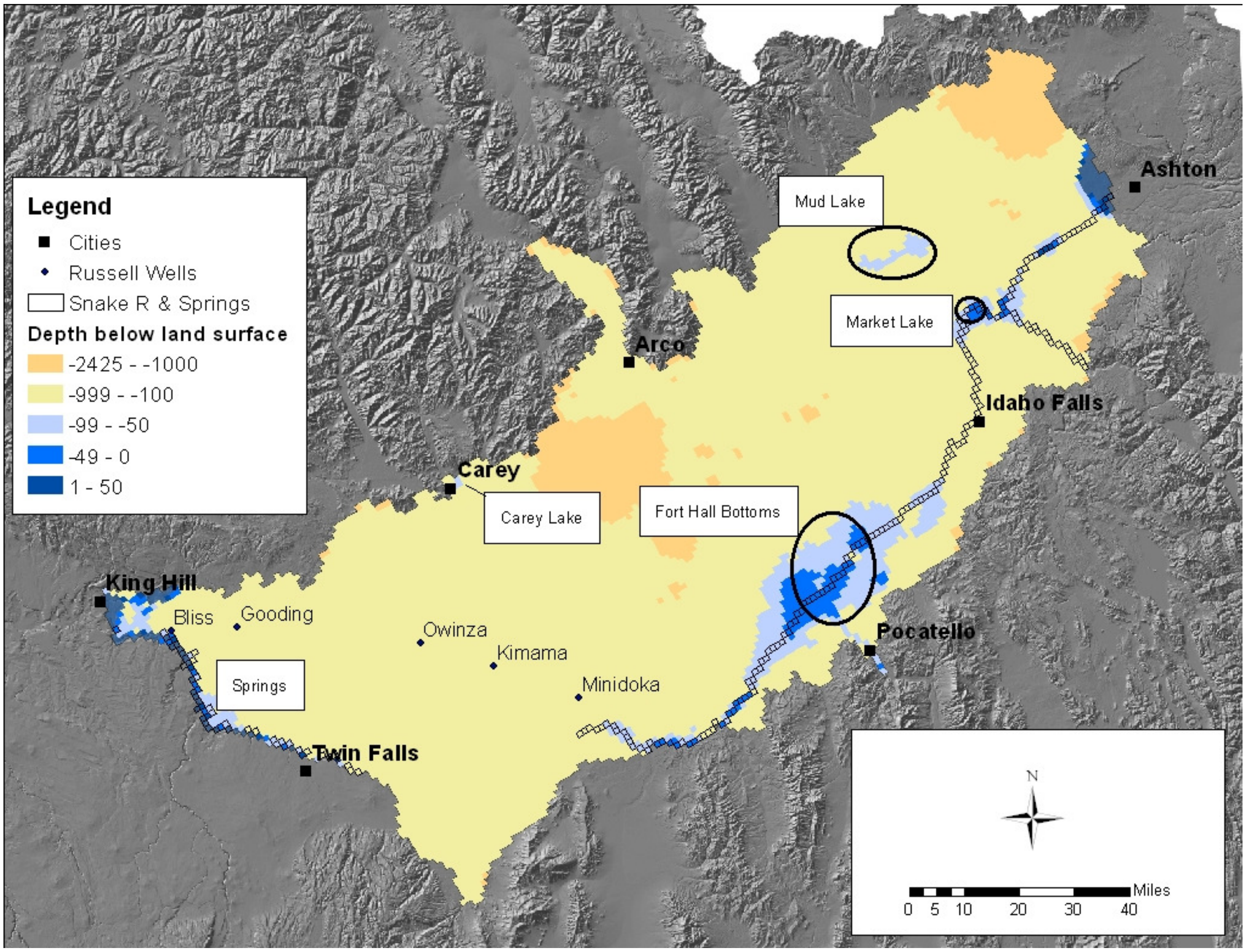


Figure 13. Modeled and observed wells, springs, and wetlands c. 1900.

Individual spring discharge

Spring discharge measurements collected by Jay D. Stannard in the Magic Valley in 1902 are recorded in the Biennial Report of the State Engineer (Ross, 1902). These measurements are compiled by spring or spring reach in Table 2.

Table 2. Spring discharge measurements/estimates from Stannard recorded in Ross (1902).

Spring(s)	Discharge (cfs)	Comments
3 to 2.25 miles above Twin Falls	36.22	Sum of 14 springs (one measured, 13 estimated), some may be on south side
Devils Washbowl	1.15	Sum of two measurements
Devils Corral	18.4	Sum of three measurements
1065027	8.83	Sum of five measurements and one estimated flow
1064026	2.43	Sum of two measurements
Blue Lakes	86.37	Measured
Trail Springs (Ellison Springs, Cells 1059022 & 1058021)	13.93	Springs below Auger Falls for 1.5 miles (27 estimated and one measured)
Crystal Springs	306.7	Sum of two measurements and one estimated flow (2.5 cfs)
Smalley's Spring (Niagara)	106.75	Measured
1051014	0.25	Estimated
1050014	0.5	Estimated
Clear Lakes	150.1	Sum of two estimated flows
Briggs Spring	77.15	Measured
Banbury Cold Springs	65.91	Measured
Blind Canyon	1.5	Estimated
Box Canyon	450	Estimated
Springs at or below river level between Box Canyon & Blue Springs	94.1	Sum of 10 estimates
Blue Springs	48.47	Measured
Sand Springs	28.51	Measured
3/4 mile below Lewis Ferry, 1045012	17.47	Measured
Thousand Springs & Magic Springs	797.44	Sum of eight measurements and four estimates
Vaders Creek (Bickel Springs)	10.29	Measured, part of National Fish Hatchery
Riley Creek	137.13	Measured, part of National Fish Hatchery
1/4 mile below Riley Creek	31.88	Measured, appears to be Tucker (cell 1042012)
Hagerman Valley springs	87.5	Sum of six estimates
Billingsley Creek	54.35	Measured, but location of section is unknown.
Between Billingsley and Malad (exclusive)	23.84	Sum of two measurements and six estimates
Malad Springs	1090	Measured
Springs below Malad	10	Estimated

Figure 14 shows the springs used as transient targets for calibration of ESPAM2.0 for which observations were also collected in the 1900 timeframe. Stannard (Ross, 1902) collected discharge measurements in a manner that allowed most of the ESPAM2 transient target springs to be compared with observations from 1902. Stannard estimated Clear Lake, Box Canyon Spring, and Thousand Springs and all three were ESPAM2.0 transient targets. Stannard also measured Billingsley Creek, which drains much of the Hagerman Valley, but it does not appear that either Rangen or Three-Weatherby Spring, which were used as calibration targets in ESPAM2.0, were measured or estimated individually.

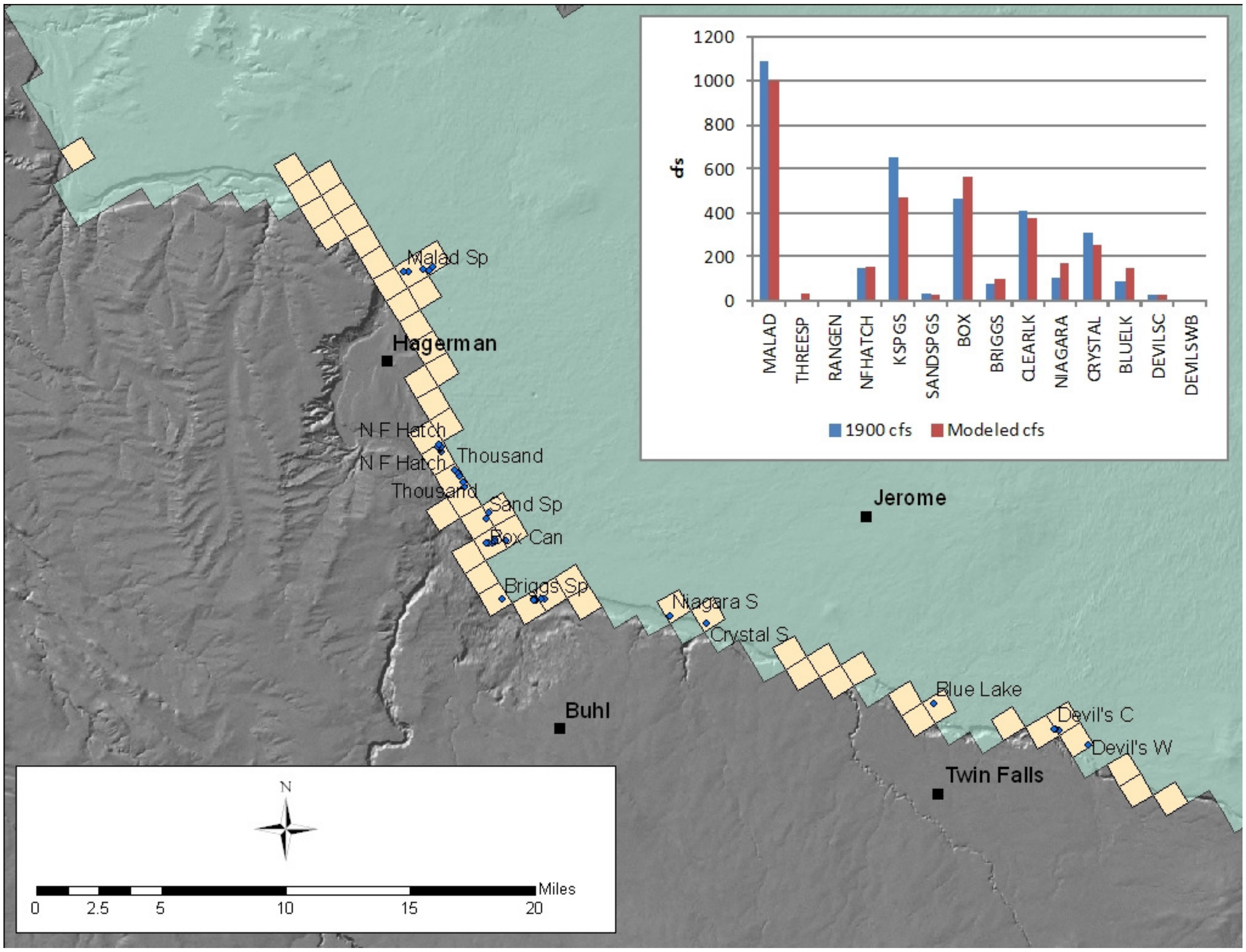


Figure 14. Location of springs used as transient calibration targets and measured or estimated by Stannard (Ross, 1902).

Stannard's estimate for Clear Lake was replaced by a 1913 measurement of 410 cfs (Nace, 1958) and Stannard's estimate for Box Canyon was replaced by a 1911 measurement of 465 cfs (Nace, 1958). Thousand Springs does not appear to have been accurately measured until construction of the Thousand Springs Power Plant, so an average of the Russell (1902) and Stannard (Ross, 1902) estimates were used for comparison with the model results. Russell estimated 500 cfs, and Stannard estimated 797.4 cfs, the average of these is 648.5 cfs. Table 3 contains the resulting spring discharges recorded at or near 1900 used in the ESPAM2.0 1900 model validation scenario.

Table 3. Comparison of 1902 spring discharge observations and modeled spring discharges. 1902 values were collected by Stannard and recorded in Ross (1902) unless noted otherwise.

Spring	1900 cfs	Modeled cfs	Residual
MALAD	1090	1003.11	86.89
THREESP		27.86	
RANGEN[1]		0.00	
NFHATCH	147.4	151.66	-4.26
KSPGS[2]	648.7	467.59	181.11
SANDSPGS	28.5	23.23	5.27
BOX[3]	465	563.38	-98.38
BRIGGS	77.2	99.11	-21.91
CLEARLK[4]	410	374.03	35.97
NIAGARA	106.8	172.23	-65.43
CRYSTAL	306.7	254.93	51.77
BLUELK	83.2	144.03	-60.83
DEVILSC	21.5	22.01	-0.51
DEVILSWB	1.15	0.00	1.15
no measurements			
estimates			
better targets			

[1]Rangen elevation 3138, watertable in 1900 validation 3136

[2]Average of Russell (1902) pg 27 & Stannard (1902) estimates

[3]Nace and others (1958) pg 41 (measurement in 1911)

[4]Nace and others (1958) pg 34 (measurement in 1913)

Spring reach Kimberly-King Hill

Assuming that Stannard (Ross, 1902) measured or estimated all of the springs between the Kimberly and the King Hill gages, then the sum of the reported values could be compared to the sum of the modeled spring discharges in that same reach. Table 4 shows the measured or estimated spring discharges with estimates for Clear Lakes and Box Canyon Spring replaced with the measured values found in Nace (1958). The total for the spring discharges around 1900 is 3,883 cfs and the total modeled discharge is 3,720 cfs.

Table 4. Total discharge of springs from Stannard (State of Idaho, 1902) unless noted otherwise.

Spring(s)	Discharge (cfs)	Comments
3 to 2.25 miles above Twin Falls	36.22	Sum of 14 springs (one measured, 13 estimated), some may be on south side
Devils Washbowl	1.15	Sum of two measurements
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1065027	8.83	Sum of five measurements and one estimated flow
1064026	2.43	Sum of two measurements
Blue Lakes	86.37	Measured
Trail Springs (Ellison Springs, Cells 1059022 & 1058021)	13.93	Springs below Auger Falls for 1.5 miles (27 estimated and one measured)
Crystal Springs	306.7	Sum of two measurements and one estimated flow (2.5 cfs)
Smalley's Spring (Niagara)	106.75	Measured
1051014	0.25	Estimated
1050014	0.5	Estimated
Clear Lakes	410	Nace (1958) pg 34
Briggs Spring	77.15	Measured
Banbury Cold Springs	65.91	Measured
Blind Canyon	1.5	Estimated
Box Canyon	465	Nace (1958) pg 41
Springs at or below river level between Box Canyon & Blue Springs	94.1	Sum of 10 estimates
Blue Springs	48.47	Measured
Sand Springs	28.51	Measured
3/4 mile below Lewis Ferry, 1045012	17.47	Measured
Thousand Springs & Magic Springs	648.7	Average of Russell (1902) & Stannard (1902) estimates
Vaders Creek (Bickel Springs)	10.29	Measured, part of National Fish Hatchery
Riley Creek	137.13	Measured, part of National Fish Hatchery
1/4 mile below Riley Creek	31.88	Measured, appears to be Tucker (cell 1042012)
Hagerman Valley springs	87.5	Sum of six estimates
Billingsley Creek	54.35	Measured, but location of section is unknown.
Between Billingsley and Malad (exclusive)	23.84	Sum of two measurements and six estimates
Malad Springs	1090	Measured
Springs below Malad	10	Estimated
Total	3883.33	

Summary and Conclusions

The data used to extend the model for the 2009-2010 validation scenario are much richer than the data used to develop the 1900 validation. The 1900 validation scenario required approximating tributary underflow, non-irrigated recharge, perched river seepage, and ET using the average of 1988-1992 based on the similarity of the average precipitation for the two time periods. No adjustments to the input data for either validation scenario were made, and no adjustments to the ESPAM2.0 model were made to improve model fit with validation data.

Because the 2009-2010 validation data are comparable in quality to the calibration data, statistics can be used to facilitate scenario evaluation (Figures 2-9). The unweighted RMSE and MAD for the 2009-2010 validation period fell within the bounds generated from the calibration period, the weighted RMSE and MAD also fell within the bounds for generated from the calibration period for every category except for spring discharges. The unweighted comparisons form RMSE and MAD with the calibration and validation data sets are more similar to the human perspective and the weighted RMSE and MAD comparison between the calibration and validation data sets represents the PEST perspective. This suggests that the match between model output and field observations during the calibration period and during the validation period might look comparable to us, and not comparable to PEST. Much of the misfit appears to be with Blue Lakes, when Blue Lakes is removed from the validation set, the weighted statistical comparison for the A&B Springs is improved (Figure 15). Only the RMSE and MAD for weighted A&B Springs falls outside the range of values produced during calibration, and much of that misfit is due to one spring, thus the 2009-2010 scenario does not invalidate ESPAM2.0.

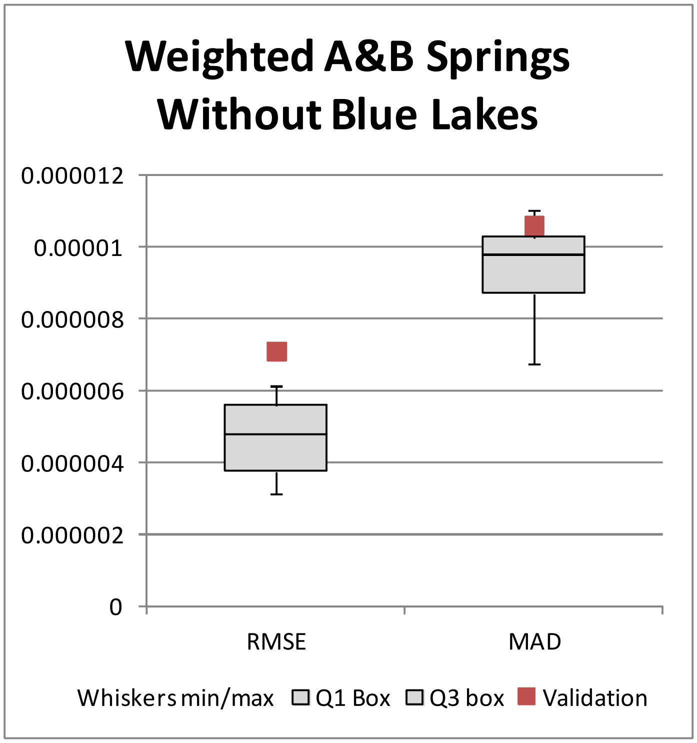

Figure 15. Weighted comparison statistics RMSE and MAD for Blue Lakes removed.

Because the limited data for the 1900 validation scenario and the model input data tend to be approximations more often than based on field measurements, the evaluation is more qualitative. Figure 16 shows the comparison between the head observations and spring discharges. Recall that landslides may have altered the springs near Bliss, possibly changing the local hydrology and water levels. Also recall that no one appears to have collected an accurate field measurement of the Thousand Springs discharge (KSPGS in Figure 16).

Head Comparison				
Well	Source	1900 Water Level (ft)	Modeled Water Level (ft)	Residual
GOODING	Russell	3463	3329	134
OWINZA	OSL	3865	3919	-54
KIMAMA	OSL	4007	4004	3
MINIDOKA	OSL	3906	4008	-102
BLISS	OSL	2841	3067	-226
OSL - Oregon Short Line Railroad				

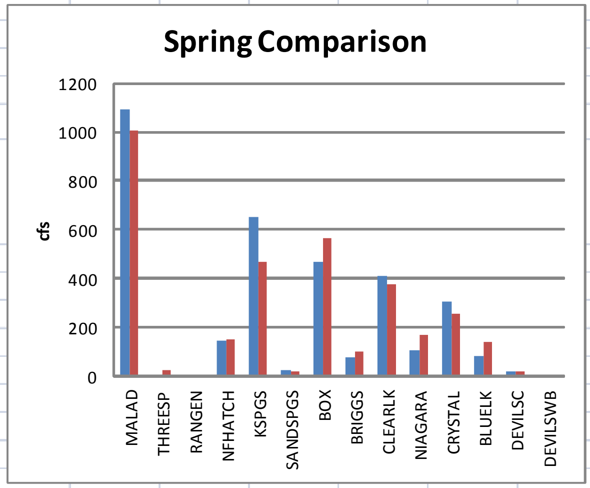

Figure 16. Comparison between modeled and observed water levels and spring discharge.

The model appears to fit the field observations well given the nature of the input data. Neither the 2009-2010 nor the 1900 validation scenarios generated significant concerns or limitations regarding the use of the ESPAM2.0.

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